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PHYSIOLOGICAL WORK CAPACITY AND PERFORMANCE OF SOLDIERS FOLLOWI--ETC(U)
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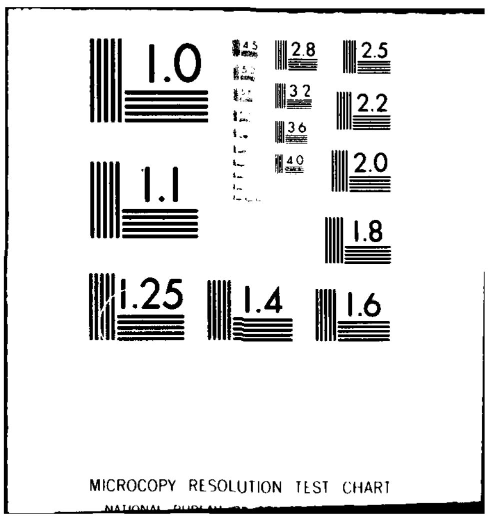
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PHYSIOLOGICAL WORK CAPACITY AND PERFORMANCE OF SOLDIERS FOLLOWING TRANSATLANTIC DEPLOYMENT

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Introduction

Current military threat analyses indicate a likelihood that prior to future conflicts there will be an extremely limited period for pre-deployment preparation and, furthermore, that following deployment, replacements will be moved to the combat zone as rapidly as possible (i.e., a "come-as-you-are" war). Such analyses have led to U.S. military contingency plans which call for large scale troop deployment by air. The capability to transport and deploy large military forces over long distances by air, although a relatively recent technological achievement, has significantly influenced both international political philosophies and military strategies. Careful consideration has been accorded the aircrews that operate the now conventional super transport aircraft. However, it is essential that equal consideration be given our ultimate weapon, the individual soldier.

Soldiers traditionally have proven to be flexible, well-motivated, and capable of great personal and group ingenuity and adaptation in the face of a diverse variety of stresses. Such characteristics have made for fighting forces able to go almost anywhere, at any time, by any means, and remain operationally effective.

Certain human parameters of personal adjustment and adaptation are, nevertheless, relatively slow and inflexible. Among these are requirements for nourishment, rest, exercise, warmth, shelter, periods of quiet, and physical and psychological support. Man does not adapt

immediately to sudden environmental changes, e.g., sea level to high altitude, equatorial to arctic, etc. The human response to such environmental alterations or deprivations, until accommodation occurs, covers a wide physiological and psychological range. These responses are to some extent understood and predictable. Irrespective of the mechanism(s) involved and whether the traveler is a soldier or civilian, the ultimate result seems to be a generalized reduction in the efficiency of the individual, particularly in mental and cognitive functions. From a military perspective, any advantages provided by advanced battlefield command and control/intelligence systems could be nullified by a stress which rendered data comprehension or decision making more difficult, or which can lead to malaise, fatigue, and a loss of physical ability or endurance in the individual soldier.

Rapid aerial deployment would necessarily entail not only the temporary desynchronization of normal circadian rhythms and geographic disorientation as in the case of a transatlantic deployment, but also a loss of sleep, possible food deprivation and dehydration, and exposure to aircraft noise and vibration (1). It is commonly believed that the symptomatology associated with jet-lag is sufficiently disruptive to interfere with the ability of athletes to perform maximally in a competitive event (2). Furthermore, it has been suggested that the effects of rapid translocation are likely different, and possibly more pronounced, in soldiers flying in troop configured transport aircraft than in business persons traveling commercially (1, 3). It is therefore not surprising that during deployment training exercises such as "Reforger", commanders have observed a general malaise and reduced performance of troops upon arrival in Germany.

In July 1977, the Commander in Chief of US Army Europe requested information on whether and, if so, to what extent, the effects of rapid transatlantic deployment would impair the health and operational effectiveness of troops. Information could be provided only on mental and cognitive functions which have been studied in commercial travelers and aircrew personnel ~~(4-11)~~. However, since no data were available on physical work performance capacities, the assistance of the Army Surgeon General was requested to define the scope and determine possible remedies for this critical combat readiness problem. This paper discusses a survey which was conducted ~~Consequently, this laboratory has tasked~~ to study the effects of translocation (jet-lag) on the ability of infantry soldiers to perform heavy physical work.

Methodology

Subjects for this investigation consisted of soldiers from rifle and headquarters companies of the 5th Battalion, 7th Brigade,

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1st Cavalry Division that were being permanently transferred from Ft. Hood, TX to West Germany. Ninety-four of the 97 soldiers who were present for the informed consent briefing volunteered for the study. Thirteen subjects were excluded from the study as a result of a medical examination, leaving 81 as the starting sample. These 81 subjects were then randomly assigned to three groups for the purposes of testing. In general terms, ninety percent held ranks between E-3 and E-5 with the majority having less than 5 years time in service. Seventy percent were assigned to MOSs 11B or 11C, infantryman. Thirteen percent were medics, 91B. The sample was representative of the Army wide enlisted population in age, height, weight and race (12).

The study employed a pre-post deployment test design. Subjects underwent five days of testing one week prior to deployment and again during the first 5 days after their arrival in Germany. The subjects departed Ft. Hood on a DC-8 chartered commercial air craft at 0200 hrs and arrived in Nuremberg at 2245 local Nuremberg time. With intermediate stops in Philadelphia (1 hr) and Shannon, Ireland, (1/2 hr), total in-transit time was 14-3/4 hours, over 6 time zones. From Nuremberg, the subjects were moved by commercial bus to the test site, Wildflecken Training Center, arriving there at 0115 hrs local time. They were billeted by 0300 hrs, awakened at 0600 hrs, and reported for testing at 0730 hrs, allowing for 8-3/4 hrs between flight touchdown and commencement of testing.

Since the ability to carry out physically demanding tasks is dependent upon motivation as well as the various physiological capacities, this study was designed to examine both the physiological (strength, anaerobic and aerobic) as well as behavioral aspects and their integrated effects on task performance. Subjects were administered behavioral (symptoms) questionnaires (13) twice daily but were tested in only one fitness component each day as follows:

Day:	1	2	3	4	5
Group					
Red	A	P	S	A	P
Green	P	S	A	P	S
Yellow	S	A	P	S	A

A = aerobic power testing section
S = muscle strength testing section
P = task performance testing section

Aerobic power was determined by the most direct means - the determination of maximal oxygen uptake during uphill treadmill running, following the procedure of Mitchell et al.(14). In order to assess possible changes in the subject's own perception of his effort against actual work intensity, ratings of perceived exertion were recorded after each run using the Borg scale (15).

This is a psychophysical scale that is numbered from 6 to 20, with the uneven numbers anchored with descriptive terms, i.e., 9-very light, 13-somewhat hard, etc. Subjects were told to combine all sensations and feelings of physical stress, effort and fatigue and to thus concentrate on their total feeling or exertion.

Isometric strength of three muscle groups was measured with a device designed in our laboratory (16) and similar to that developed by Hermansen (17). The three muscle groups tested were: (a) the upper body (arm and shoulder), (b) legs and (c) back (trunk). Three contractions of each muscle group were performed, each 3-4 seconds. The force was registered on a spring-loaded force transducer connected to a bar against which the subject exerted force. In all cases the subject was instructed and encouraged to exert as much force as possible.

Dynamic muscular strength and endurance of two muscle groups, the arm flexors and knee extensors, were determined utilizing isokinetic (constant velocity) measuring equipment (Cybex II dynamometer, Lumex Corp., Cybex Div., Bay Shore, NY). The isokinetic device allows the subject to exert a maximal voluntary contraction at a constant velocity and thus allows the production and quantification of maximal force (torque) throughout the range of motion (18). Dynamic strength was assessed with two individual contractions for each muscle group at each of two contractile velocities, 36 and 180 degrees per second. Muscle endurance was quantified from a 60 second bout of repeated maximal contractions at 180 degrees per second.

In order to insure the successful execution of combat duties under any and all conditions, soldiers should be capable of performing the basic tasks of running, climbing, and carrying. A field task performance battery was therefore developed from events which reflect ability in basic military physical skills such as those which are essential both to personal safety and to effective combat operations. The tests selected were as follows: 6 meter rope climb; 110 m fireman carry of another soldier of similar body weight; 270 meter sprint; and a 2.8 km run. The performance criterion in each case was time.

The data were analyzed by means of one-way analysis of variance for repeated measures. The level of significance selected was $p < 0.05$.

Results

The subjective symptomatology survey indicated that there was a significant increase in symptom reporting after arriving in Germany (Figure 1). Of these symptoms those which disappeared or were significantly diminished by the 5th day included: headache, light headedness, dry mouth, sore throat, blocked nose, trouble sleeping and tense and aching muscles. While the symptoms of running nose, tiredness, sleepiness and irritability were still high on day 5, none were statistically higher than baseline day 1 in Texas.

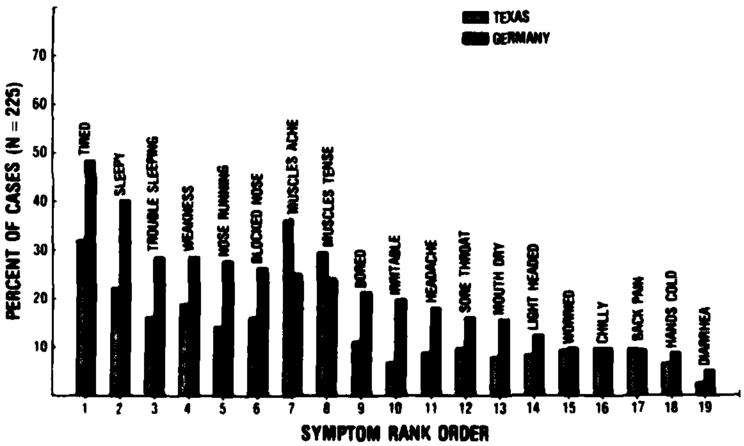

Figure 1. Rank order of symptoms based on percent reported during the five days in Germany. Number 1 through 6 and 9 through 12, were significantly higher ($p < .05$) following deployment.

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A rough indicator of the importance of these symptoms was the number or percentage of individuals affected in Germany. Over 50% of the 45 men on whom complete data were collected reported problems with fatigue and trouble sleeping, more than 40% reported weakness and more than 30% reported problems with nasal congestion, aching muscles and irritability. Slightly more than 20% reported having headaches, light headedness, dry mouth and feeling bored. Approximately 10% reported having cold hands and feeling chilly. Less than 10% reported diarrhea and feeling worried. Since the sample is biased toward those who felt motivated and well enough to complete all questionnaires, the above results are, at best, underestimates of the true incidence of these symptoms (Figure 2).

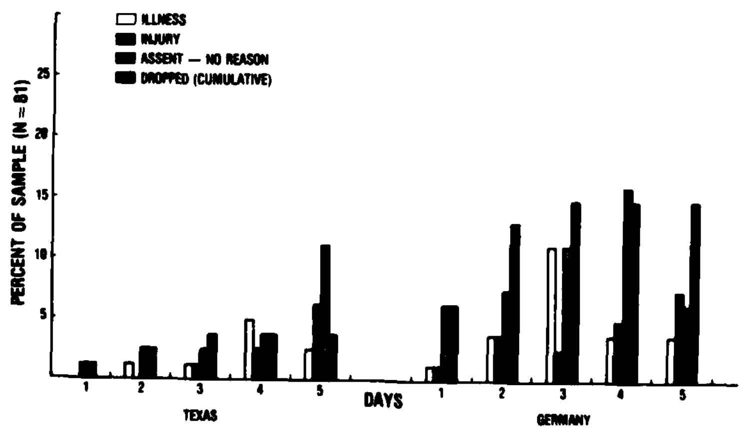

Figure 2. Percent of sample (n = 81) not completing tests each day.

The results of the treadmill aerobic performance tests included evaluation of heart rate, ventilation, oxygen consumed, and relative perceived exertion at both submaximal and maximal workloads. Despite the symptomatology reported, no significant differences were noted in any of these parameters including perceived exertions with the

(44)

exception of a 5% increase in submaximal $\dot{V}O_2$ in one group on the third day in Germany (Table 1).

Table 1. Aerobic Capacity Measures, Mean Values.

	Texas	Germany
1. Heart Rate (Beats/min)		
a. Submaximal*	165	164
b. Maximal	193	194
2. $\dot{V}_E$ (l/min, BTPS)		
a. Submaximal*	73	75
b. Maximal	130	132
3. $\dot{V}O_2$ (ml/kg/min)		
a. Submaximal*	33.8	34.2
b. Maximal	47.0	47.9
4. RPE		
a. Submaximal*	11.1	9.6
b. Maximal	16.0	15.7

*Submaximal refers to values recorded during the sixth minute of a run at 6 mph on a zero percent grade.

Changes in isometric strength following translocation were generally small, inconsistent and statistically insignificant (Figure 3). Dynamic arm strength was lower in every case following translocation (Figure 4). The percentage differences for test days one through five at a velocity of 36°/sec were 12.2, 4.0, 1.0, 3.2 and 7.8, respectively. The comparable differences at 180°/sec were 19.7, 5.7, 11.6, 11.3 and 6.0 percent. No strength scores recorded in Texas for a given group were statistically different from one another, nor were those recorded in Germany different from one another. If scores from each location for each group are combined to provide a single strength value for comparison, strength is found to be reduced significantly at both contractile velocities for all groups except the red group at the slower speed. For analysis of dynamic arm endurance, values of all groups were combined into single pre- and post-translocation scores (Figure 5). Analysis of variance indicated significant reductions in peak torque ($\bar{x}$:16.9%) for all contractions up through and including the thirty-third. Translocation thus appeared to have

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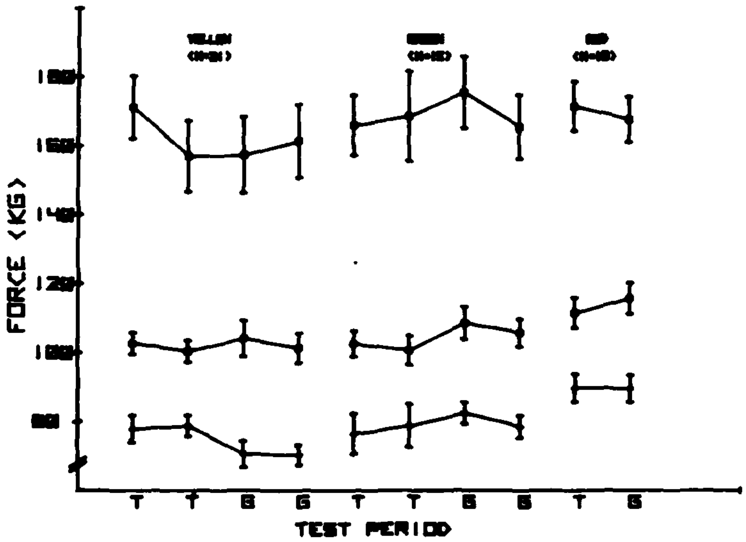

Figure 3. Isometric strength of legs, upper torso, and trunk extensor muscles (upper, middle and lower lines, respectively). T:Pre-deployment (Texas) values; G:Post-deployment (Germany) values.

a detrimental effect on dynamic strength and endurance of the elbow flexor muscles.

Dynamic leg strength scores are depicted in Figure 6. For the yellow group a higher strength score was obtained in test period 1 than test periods 2, 3 and 4 at both velocities. There were no other significant differences within this group. For the green group at 36o/sec the only significant difference was between the two test periods in Texas. For the green group at 180°/sec leg strength declined significantly from the first test period to the second (in Texas), but by the time of testing in Germany, values had risen significantly to equal those obtained in the first period. The red group demonstrated significantly higher strength in Germany than in Texas.

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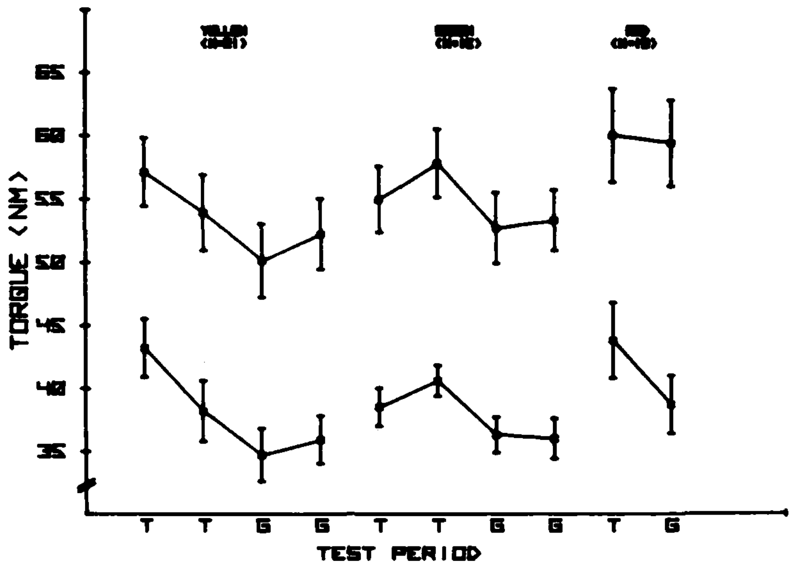

Figure 4. Peak strength (torque) exerted by elbow flexors at 36 (top) and 180 (bottom line) degrees per second. T:Texas; G:Germany.

At both velocities a steady decline in dynamic leg strength is seen from test day 1 to test day 3. The mean scores for the yellow group (strength tested on day 1 in both locations) are approximately the same as for a large sample of subjects from the 2d Infantry Division tested on the same apparatus (19). By the second day the green group shows a considerable and significant decline in strength when compared to the yellow group. This is especially surprising since the two groups are approximately equal on the other strength parameters. Strength values of the red group, tested on the third day, are below those of the green group. On most of the other strength parameters the red group demonstrated higher values than the other two groups. On day 4, the yellow group shows a further decline over their previous score as does the green group on day 5.

This pattern of declining scores suggests a fatigue effect due to the intense and repetitive pattern of testing. Both the

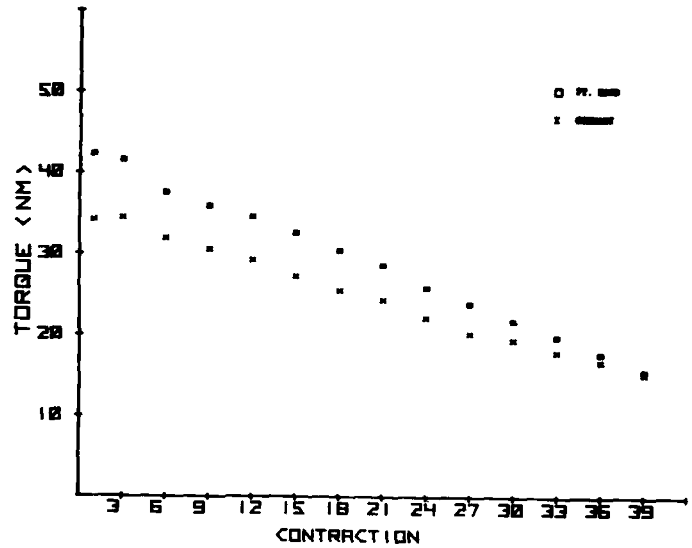

Figure 5. Dynamic arm endurance at 180°/sec for all test groups combined. Differences were statistically significant at all contractions except 36 and 39.

aerobic power and field performance tests primarily stressed the lower body and the relatively short recovery times (24 hrs) allowed between test sessions may have adversely affected the dynamic leg strength scores. This hypothesis is partially substantiated by the subjects' evaluations of "muscle aches" on the symptoms questionnaire. At Ft. Hood on day 1 only 13.3% of the individuals in the green group reported "muscle aches" (15). But on day 2 following field performance and just prior to muscle strength testing, 46.7% of these subjects reported aches. 57.1% of the red group reported muscle aches on day 3 following treadmill and performance testing. In yellow and green groups, 53.3% and 46.7% of the subjects reported aches on days 4 and 5, respectively, following the field performance testing. It thus appears that the dynamic leg strength scores were to some extent confounded by the fatigue of repetitive testing. That is, the fatiquing effects of hard physical work outweigh or at least mask any effects of translocation on laboratory measures of muscle strength.

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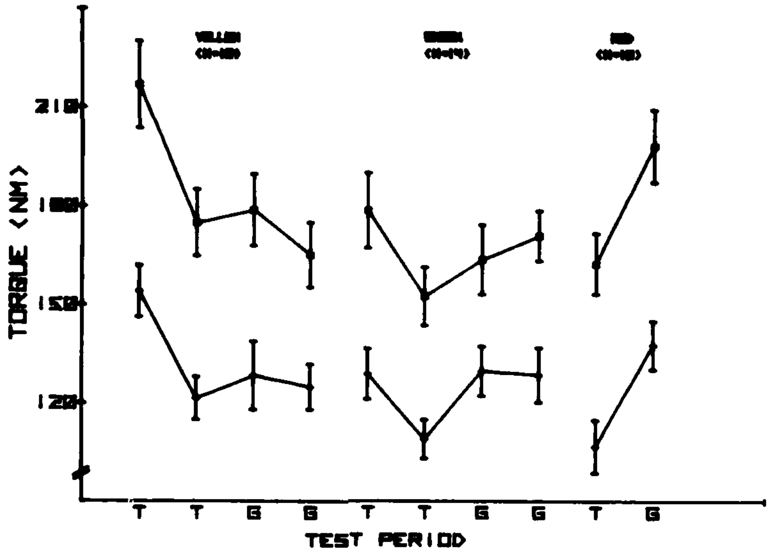

Figure 6. Peak strength (torque) exerted by knee extensors at 36 (top) and 180 (bottom line) degrees per second. T:Texas; G:Germany.

The pattern of scores for dynamic leg endurance mirrors the results of the dynamic leg strength data. The yellow group shows the least endurance decrement on all contractions in test period 1 in Texas. The green group exhibits a larger decrement than the yellow group in their initial test while the red group decrement was even more marked than the other two groups on test 1. Further performance depressions were seen on test 2 in Texas for the yellow and green groups. As with dynamic leg strength, it is likely that fatigue from the field performance and treadmill tests influenced the dynamic leg endurance measures.

Performance on the four selected military physical tasks is illustrated in Figure 7. No decrements were observed in the rope climbs (testing overall upper body strength and coordination), man-lift and carry (back and leg strength, anaerobic capacity and coordination), or 2.8 km run (cardiorespiratory function).

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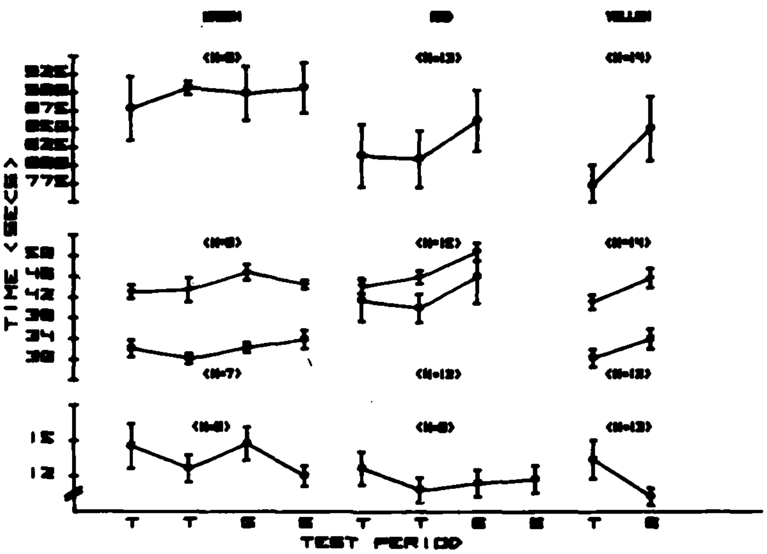

Figure 7. Performance times in military physical tasks, top to bottom: 2.8 km run (top), 270 m rush, 110 m fireman carry, and 6 m rope climb (bottom).

The 270 m rush was included to assess leg muscle power, anaerobic capacity and overall body coordination. Scores on this test were variable but not statistically different within or among groups over the five days of testing at Ft. Hood. Following arrival in Germany however, average performance times increased in all groups. Performance decrements were recorded for 49 of the total of 52 soldiers tested on the first three days in Germany. Analysis of the times of each test group indicated that while neither the green nor the yellow group experienced a statistically significant reduction in performance following translocation, the red group completed the sprint on the second day in Germany at a significantly slower pace than in Texas. Two basic interpretations of this finding may be offered. One is the possibility that the decrement resulted from an impairment or alteration in some physiological function or process that influences anaerobic power capacity. A second interpretation is that the jet-lag (or jet-lag plus testing) effects were on psychological parameters which,

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in the case of one group, experted a significant negative influence on the motivation to perform work.

Discussion and Conclusions

Behavioral responses commonly reported for transatlantic travel were observed and confirmed in a majority of the subjects in this study: tiredness, sleepiness, weakness, headache and irritability. While most symptoms had disappeared or significantly diminished by the fifth day in Germany - tiredness, sleepiness and irritability still persisted at that time.

While static (isometric) strength of upper body, legs and trunk was unchanged, dynamic strength of arms was reduced after arrival in Germany in two out of three groups at the slow contraction speed and in all groups at the fast velocity. Dynamic leg strength appeared to be less affected by translocation than by the fatigue of repetitive testing. Measures of both arm and leg muscular endurance (anaerobic power) declined significantly after arrival in Germany. The finding was generally consistent in all test groups, although fatigue from other testing may again have confounded the leg endurance findings. Aerobic power was completely unaffected by translocation. Oxygen transport capacity and aerobic muscle metabolism for sustained whole body activity appears to be unaffected by the conditions experienced in this study.

Performance of military physical field tasks (rope climp, rush, lift and carry and run), which should reflect the culmination of both psychological and physiological affects on work ability, was essentially unaffected by translocation. Only one group exhibited an isolated significant decrement in one event (rush). Thus, the work task performance suggested that, if present, psychological and physiological alterations were not of sufficient magnitude to alter work performance during the five days following translocation as assessed in this study.

It is somewhat perplexing that decrements were found in muscular strength and endurance capacity without concomitant changes in task performance. Assuming that our measures of capacity in fact tested the same muscle groups that were employed in the task performance, one can only conclude that the tasks were either not performed to the point of taxing the maximal capacity of the physiological systems, or were inappropriate tasks for maximally taxing the physiological systems. If we can assume that the tasks selected sufficiently represent work performance required by the combat soldier, then we can

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only conclude that physiological capacity changes are not of sufficient magnitude to affect performance from a practical standpoint.

It is impossible to resolve from the present study whether these observed alterations in muscular strength are due to the general stress resulting from translocation or due to one single component, such as biorhythm disruption or sleep loss. The stress of noise, vibration and fear often included in the description of translocation can be ruled out in this study since the movement was made in commercial aircraft, by troops who for the most part previously deployed to Germany and were adequately prepared for this permanent change of station. Despite the comforts of commercial aircraft, sleep deprivation was nevertheless a prominent finding upon arrival in Germany and evident during the first days of testing. Halloway (3) has suggested that sleep loss is likely a more dominant stress than the rhythm disruption. No studies have been found which have examined the effects of sleep deprivation per se on muscle strength and endurance. Such a study appears indicated. Aerobic power during sleep deprivation has been studied in this laboratory (Gleser and Vogel, unpublished) without any discernable effects.

In summary, the results of the study suggest that despite the behavioral and isolated physiological changes, no significant decrement in work task performance could be documented with transatlantic deployment. It can be concluded that any decrements in willingness to work or physiological capacity were insufficient to become apparent in gross work ability as measured in this study.

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